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FACTORS THAT DETERMINE SPRING RUNOFF IN THE NORTHERN ROCKY MOUNTAINS

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Foresters and other land managers in the Upper Columbia and Upper Missouri River Basins are conscious of the fact that their activities have an important bearing on spring runoff. They know that two-thirds to three-fourths of the water in the upper sections of these streams comes from forest land, much of it from the accumulated winter snows. They know that road building, timber cutting, stock grazing, and prescribed burning likely have an important effect on the quantity and quality of water produced. Residents of the towns and cities downstream and owners of farms and industrial property are conscious, too, of the headwater areas because many of them have lost homes and livelihood from past spring floods.

Although most of us recognize the importance of flood prevention work and the necessity for accurate local forecasts of spring runoff, there is little specific data available on which to establish the definite relation of spring floods to the many variables that control them. There seems to be a number of situations that can produce floods. While the Northern Rocky Mountain Forest and Range Experiment Station has not made a detailed appraisal of various spring flood conditions, records have been collected in recent years that are of interest.

Three years of contrasting situations are represented by 1948, 1950, and 1953. Severe spring floods occurred throughout the Columbia Basin in 1948 following the melting of heavy winter snows. In the spring of 1950, with an even greater snow pack, no flooding occurred. Severe local floods, especially in the Upper Missouri, were experienced in 1953 but without significant snow melt. The following case histories attempt to explain the differences among the years and point to a better understanding of spring runoff.

Columbia Basin -- 1948

The 1948 floods in the Upper Columbia and much of the lower Basin may be considered as an outstanding example of the snowmelt type of flood. Some of the factors contributing to this flood were:

1. Above-average 1947 fall rains went far in recharging the retention storage space in the soils.

2. An above-normal snow pack extended to low elevations. On April 1 the pack averaged about 110 percent of normal in the Kootenai area, 120 percent in the Flathead, 135 percent in the Upper Clark Fork, and 130 percent in the Clearwater.

3. Unusually cold weather in March, April, and early May prevented early melt and kept the snow pack intact even to low elevations so that a large portion of the watershed was still covered with snow as late as the middle of May.

4. About the middle of May a large warm airmass moved into the Basin and stayed for two to three weeks causing simultaneous and sustained melting of the extensive snow cover, even at high elevations, on all aspects and under all cover conditions. Thus, instead of the normal natural scheduling of runoff, first from low elevations, south slopes and open areas followed by progressive melting and runoff at higher elevations, on north slopes and timbered areas, all these areas were contributing simultaneously.

5. The normal, natural diurnal scheduling of runoff was also upset. Normally, the daily peak from a minor tributary entering near the mouth of a larger stream is out of the way before the daily peakflows from the minor tributaries near the head of the stream have come down. In 1948, with the day and night melt, flow from the tributaries piled up in the larger streams.

6. Rain was important in some areas, but since the few recorded thunderstorms did not occur over large areas simultaneously they probably had little effect on the overall flood conditions although they did contribute to local flooding. Most of the Upper Columbia received the normal amount of rain during the snowmelt period.

7. The extensive nature of, first, the cold spring conditions which retarded melt basinwide, and, second, the large warm airmass which brought sustained melt basinwide were unusual. Thus, not only diurnal but natural geographic scheduling of peakflows was upset. Nearly all headwater areas were in flood stage at the same time so that when peakflows from all major tributaries converged on the lower Columbia simultaneously the flood was even more disastrous there than in the upper reaches.

The 1950 Situation

In the spring of 1950 it appeared that the stage was set in the Upper Columbia for a worse flood than in 1948, as indicated below.

1. Although the fall of 1949 was not quite as wet as that of 1947, fall moisture averaged about normal or a little above so the soil storage space was well filled beneath the snow pack.

2. The snow pack was even greater than in 1948. On April 1 the pack was 145 percent of normal on the Kootenai, 140 percent on the Flathead, 130 percent in the Upper Clark Fork, and 160 percent in the Clearwater.

3. March and April were cold and melt had hardly begun by the first of May, even at rather low elevations. As in 1948, a large part of the watershed area was still snow covered when the melt began.

Because of these conditions Forest Service research teams were stationed high in the Kootenai, Flathead, and Clearwater watersheds to study and collect data on snowmelt, climatic conditions, and streamflow during the snowmelt season. Progress of the melt was documented by weekly measurements of numerous snow courses located at various elevations, on all aspects, and under various types of forest cover as well as in the open. Daily temperature and precipitation measurements were maintained in strategic locations at each study area. These data were correlated with records from the nearest stream gage.

Following is a brief summary of some of the findings which seem to suggest why serious flooding did not occur in 1950:

1. The 1950 melt period, which began about the second week in May, was broken every three or four days by a cool period. During a few days of warm weather the runoff would build up until streams were about bankfull. Then during subsequent cooler weather the streams would drain out and the process would start over again. In the Kootenai study area this phenomenon was repeated five times between May 10 and June 15. By this time the snow was so nearly gone that streamflow no longer responded to high temperatures. In the Flathead and Clearwater areas streamflow followed temperatures up and down six times between May 10 and June 25.

2. Comparison of 1948 and 1950 hydrographs for Bear Creek, tributary to the Middle Fork of the Flathead, shows that there was more runoff during May and June in 1950 than in 1948 with the instant highest peak nearly equal. In 1948 flow of Bear Creek stayed above 250 c.f.s. for 19 consecutive days, May 18 to June 6. In 1950 it stayed above 250 c.f.s. for only 11 consecutive days, June 11 to 22. But in 1948 it stayed above 150 c.f.s. for only 26 consecutive days compared to 55 days in 1950.

3. In 1950 the extreme peak on Bear Creek occurred after four inches of precipitation which came as about nine inches of snow followed by two warm days with rain. In 1948 the Bear Creek peak followed a week of warm weather with but little precipitation. The 1950 precipitation was not general and therefore the Bear Creek peak did not coincide with peaks on many other small streams and flooding was only local.

4. Melting in 1950 was caused by what might be described as normal spring weather, a few weeks late. Natural scheduling of streamflow operated effectively. Therefore, although streams were high, the runoff took place with little flood damage anywhere.

5. Since melting was caused largely by sunshine, instead of a warm air-mass as in 1948, the snow went first at low elevations, on south slopes, and in the open. Snow course measurements show that open courses were bare an average of 10 days earlier than courses in the timber.

The Spring of 1953

In 1953 serious flooding occurred in some parts of the Northern Rocky Mountain area. Though this was during the snowmelt period, it was not a typical snowmelt flood like that in 1948. The following facts are relevant to behavior of the runoff:

1. Fall 1952 precipitation was far below normal.

2. Snows, when they came, fell on dry ground at high elevations.

3. January 1953 was unusually mild and wet bringing rain at low elevations and snow at high. February was also milder and wetter than normal.

4. The snow pack continued to build up at high elevations until April but little snow ever accumulated below about 4000 to 4500 feet. On April 1 the pack in Sun River contained less water than in any of the four previous years as of that date. Six snow courses averaged 10.0 inches compared with a 13.9-inch average.

5. By May 16 roads were open at higher elevations than usual. Considerable snow at moderate elevations had melted in orderly fashion so that some forest roads were passable to about 5000 feet. Yet roads at the higher elevations remained blocked later than usual. Streams were generally low and clear on May 17.

6. By the middle of May there was little danger of major floods in the Upper Columbia and Missouri areas from snowmelt because only a relatively small portion of the watershed was still covered by snow. The remaining snow consisted of a deep pack at high elevations. This situation seemed ideal for sustaining flow well into the summer.

7. About May 24 a large, moisture-laden airmass moved into central Montana from the southeast. Cold air moved in under it from the west and a low pressure area developed in the vicinity of Great Falls. This condition continued intermittently until about June 10. As a result, an unusually large amount of precipitation occurred throughout an area which might be roughly bounded by a line connecting Butte, Drummond, Cut Bank, Lewistown, and White Sulphur Springs. During portions of the storm period stations such as Superior, Missoula, Kalispell, and Bozeman, lying outside the area described, received 24-hour amounts exceeding an inch on one or two days.

8. The storm centered in the Great Falls area where a total of 9.90 inches of rain was recorded at the official Weather Bureau station May 24 to June 3. The north and west facing slopes of the Little Belt Mountains and the Highwood Mountains received considerably more total precipitation than Great Falls. A total of 18.79 inches was measured at Shonkin, south of Fort Benton. The Conway Ranch on Tenderfoot Creek on the west slope of the Little Belts reported 14 inches of rain in the first 10 days of June. The greatest intensity measured by the U. S. Weather Bureau was 0.07 inch for five minutes at Great Falls. Undoubtedly much more intense showers occurred locally. At Shonkin more than 6.5 inches of rain fell during two different 24-hour periods.

9. Abnormally cool weather accompanied the rainy period May 24 to June 3. Some general snowmelt occurred but melt was certainly not unusually high during this period.

10. Growth of vegetation was delayed by cool weather in April and early May. Thus, plants had not drawn a normal amount of water from the soil during the first few weeks of spring. Rains fell on soil with relatively little retention storage capacity.

11. Therefore, after a few days of rain the streams began to rise, probably as a result of seepage flow from moderate and low elevations combining with normal snowmelt runoff and greatly supplemented by the heavy rainfall at high elevations.

12. Flooding in downstream areas, as in 1948, occurred because of sustained high flows from all small tributaries augmented by unusually high flows from a few tributaries which apparently received higher intensity storms than the rest. Normal scheduling of runoff was absent.

Conclusion

A variety of factors working together can contribute to spring runoff and flood conditions in the Northern Rocky Mountain region. Sometimes weather and condition of the snowpack team up to produce a disastrous flood as in 1948 on the Columbia. Favorable weather with even more critical snow packs may produce orderly runoff with a minimum of high water. Little can be done to control the weather, especially the flood-producing rains of 1953, but a better understanding of how these factors operate will enable land managers to appreciate the problems ahead in achieving the greatest practical degree of flood prevention. Programs of water resource management will then be on a sounder basis.